Monthly Report No. 3

HYDROGEN-OXYGEN APS ENGINES
NAS 3-14354

Period Ending 25 October 1970

L. Schoenman and A. A. Oare

5 November 1970

Engine Components Department
Aerojet Liquid Rocket Company
Sacramento, California

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Prepared for

NASA-Lewis Research Center
Cleveland, Ohio 44135

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AEROJET LIQUID ROCKET COMPANY

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Monthly Report No. 3

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I PROGRAM OBJECTIVES

The primary objective of this contract is to generate a comprehensive technology base for high performance gaseous hydrogen-gaseous oxygen rocket engines suitable for the Space Shuttle Auxiliary Propulsion System (APS). Durability requirements include injector and thrust chamber designs capable of 50 hours of firing life over a 10-year period with up to 10^6 pulses and single firings up to 1000 sec. These technical objectives are being accomplished and reported upon in a twenty-one task program summarized below. The first ten tasks relate to high pressure APS engines, parallel tasks eleven through twenty relate to low pressure APS engines, and task twenty-one is a common reporting task.

Task Titles	High P_c Task	Low P_c Task
Injector analysis and design	I	XI
Injector fabrication	II	XII
Thrust chamber analysis and design	III	XIII
Thrust chamber fabrication	IV	XIV
Ignition system analysis and design	V	XV
Ignition system fab and checkout	VI	XVI
Propellant valves preparation	VII	XVII
Injector tests	VIII	XVIII
Thrust chamber cooling tests	IX	XIX
Pulsing tests	X	XX

Common Task

Reporting requirements XXI

Section II of this report provides a review of the progress in the fourth program month on the high pressure engine technology portion of this contract. Low pressure engine technical progress is covered in Section III.

II HIGH PRESSURE ENGINE TECHNOLOGY

A. Program Progress

(1) Task I - Injector Analysis and Design

(a) Cold Flow Data

Analysis of the coaxial and impinging coaxial element cold flow data was completed and documented. Cold flow data for the pie and concentric ring manifolding of the impinging element design were evaluated for several manifold modifications. The modifications which reduced the oxidizer maldistribution from ± 15% to ± 5% were the elimination of sharp corners on flow controlling channels and on the inlet side of the oxidizer orifices. The fuel circuit provided the ± 5% goal on flow uniformity without modification. Measured flow distribution for this design are shown in Figure II-1 and II-2. Preliminary flow data for the oxidizer manifold of the coaxial element design with inlet swirlers indicates that the goal of ±5% on flow maldistribution has been achieved without need for modification. Data for the fuel circuit was not available at the close of the report period.

(b) Cost and Fabrication Analysis

A review of the impinging coaxial element injector manifolding design was conducted. Design modifications for achieving further improvements in flow distribution in conjunction with reduced fabrication costs were identified. Additional fabrication cost reductions via changes in fabrication procedures were also identified. Combined design and fabrication procedure modification are estimated to reduce unit fabrication costs by about 20%.

(2) Task II - Injector Fabrication

Fabrication of the 42 element coaxial element injector was completed. Brazing of the nickel elements to the CRES 304L body and of the CRES 347 photoetched swirler stacks was accomplished on a

OXIDIZER CIRCUIT (SN-2)

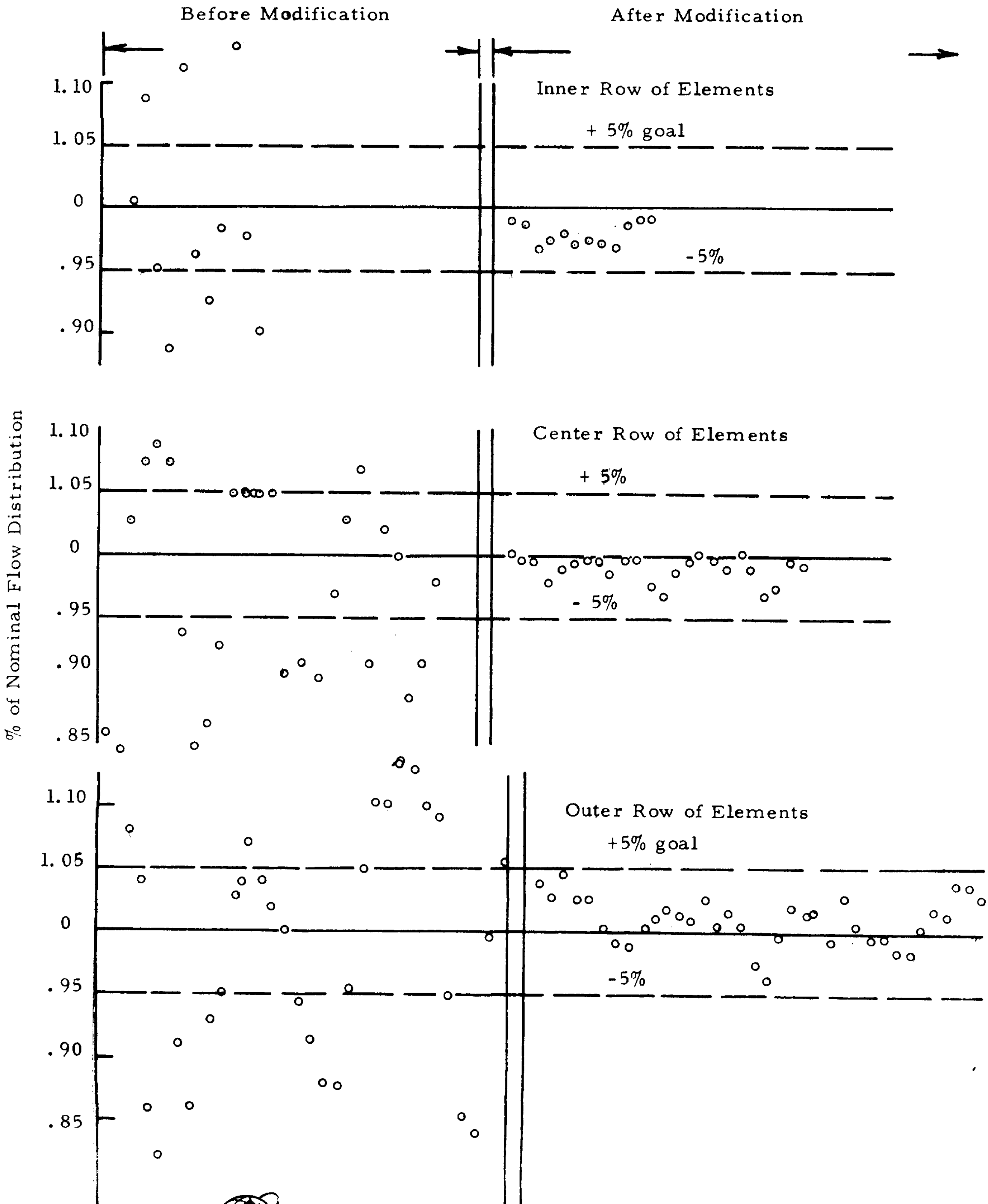

Fig II-1

FUEL CIRCUIT BEFORE MODIFICATION

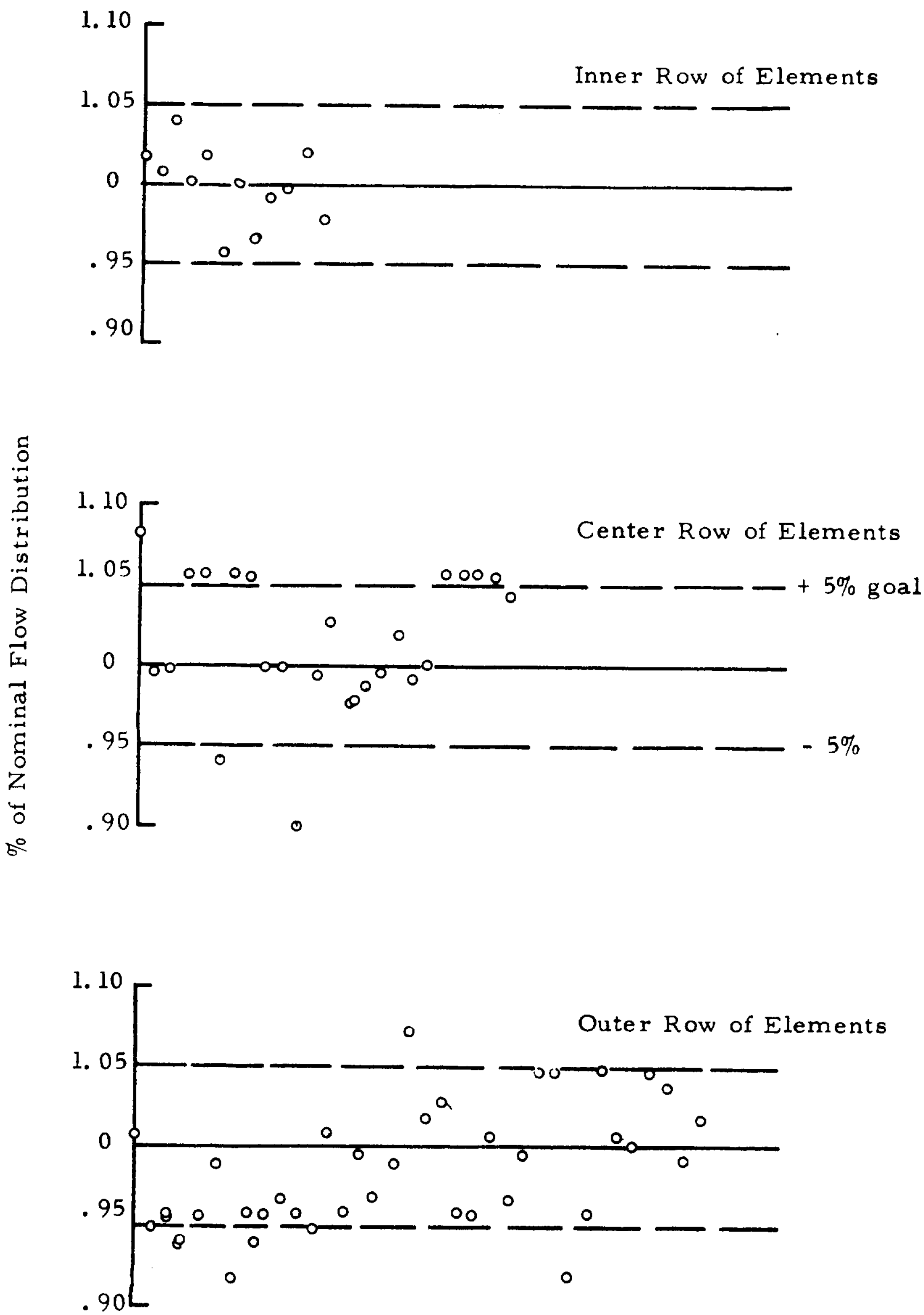

Fig II-2

II, A, (2) (cont.)

routine basis, as was final machining and assembly of the removable face plate and oxidizer cover.

Fabrication of additional injector bodies have been rescheduled until manifold cold flow tests of the first unit are completed.

(3) Task III - Cooled Chamber Analysis and Design

Analysis of cooled chambers was initiated in two areas. These include (1) thermal design analyses using experimental heat flux data available from other ALRC* programs and (2) evaluation of fabrication procedures.

Emphasis in cooled chamber design is being placed on the use of combined cooling methods. The combined processes being reviewed include regenerative, film and dump cooling. The objectives are the attainment of designs which weigh significantly less than pure regenerative cooling, lend themselves to nozzle scarfing or truncation, have lower coolant pressure drop, and approach the high performance of full regenerative cooling.

(4) Task IV - Thrust Chamber Fabrication

Bids and delivery times for forgings from which cooled chambers could be machined were received. These included various grades of high purity copper, Beryllium and zirconium copper alloys of size suitable for a full regeneratively cooled chamber. Quoted delivery times are sufficiently rapid to allow materials to be ordered at the time concept selection is finalized. Material cost for high strength copper alloys however, suggest that use of these materials be reserved for the high heat flux chamber and throat region.

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*Ref. Quarterly Progress Report # 1 NAS 3-14354, 14 Oct. 1970

(5) Task V - Ignition System Analysis and Design

Task completed - No Activity

(6) Task VI - Igniter Checkout Tests

Ambient temperature propellant checkout tests of the electrical igniter to be used in Task VIII was completed in the third report period as reported in the last quarterly. Checkout tests with temperature conditioned propellants continues to be delayed because of difficulties in getting small quantities of cold propellants to the igniter. Testing of the catalytic igniter with ambient temperature propellants was initiated at the close of the report period. Initial checkout tests appeared to be highly successful. Steady state igniter Pc is being achieved approximately .015 sec. after initiation of flow. Catalyst bed temperatures are several hundred degrees higher than anticipated, indicating bed mixture ratios may be slightly above the nominal value of 1.0. This is being further evaluated.

(7) Task VII - Valve Preparation and Checkout

Valve preparation, checkout, mounting on the test stand, actuation and cold flow testing has been successfully completed in Physics Lab, Bay 7. Valve pressure drop with ambient temperature propellants at 1.5 K thrust design flows as determined from cold flow and hot fire checkout tests are as follows:

	Flow lb/sec	Propellant Temp. ^{o}R	P_{out} psia	ΔP psid
Fuel Valve (H_2)	.69	522	354	10.9
Oxidizer Valve (O_2)	2.76	522	356	9.3

Valve dynamic characteristics are summarized in the following table.

Pilot valve type	Electrical 1/2" Marotta
Thrust Chamber Valve	Helium actuated ntrols Components 1.125 port diameter
Helium pressure	150 psia
Thrust chamber valve travel time	.006 sec. full closed to full open
Electrical signal to TC valve full open	.085 sec. fuel .100 sec. oxidizer
Pilot valve travel time	.010 sec. estimated

Thrust chamber valve travel time (full closed to full open) is sufficiently fast for the program requirements for rapid start transients. The actuation time for the 1/2" Marotta pilot valve however, is unacceptable for for pulse mode operation because of the delay between electrical signal and the start of pilot valve travel. Current plans are to replace the present pilot valve with faster acting units possibly of a smaller size.

(8) Task VIII - Injector Checkout Testing

The Bay 7 test stand in the Physics Lab has been activated and is being debugged in checkout firings using available 1.5 K heat sink thrust chambers and injectors. As of the close of the report period several hot checkout tests had been conducted. The Bay 7 test stand now contains pebble bed type hydrogen and oxygen heat exchangers of sufficient capacity to run 10 - 20 sec. test with temperature conditioned propellants. The low pressure drop fast reponse valves discussed in Task 7 are also installed on this test stand.

The coaxial element injector fabricated in Task II is in the Aerophysics Lab for manifold cold flow distribution evaluation. This unit should be available for thermal instrumentation and Task VIII hot testing in the next report period.

(9) Task IX - Cooled Chamber Testing

Planning for the J-4 altitude test facility buildup has been initiated. Current planning is to move the major portion of the test stand from the Physics Lab to the J-4 test facility. Interfaces at which the feed system and stand mountings will be broken have been tentatively identified.

(10) Task X - Cooled Chamber Pulse Testing

No Activity Scheduled

(11) Task XXI - Reports

The First Quarterly Report was submitted and distributed in accordance with the revised and expanded NASA and industry distribution list.

B. Current Problems

There are no significant technical problems in the program at this time. The program is approximately 4 weeks behind schedule because of general slippages in injector fabrication and test stand activation. The program budget is paralleling the technical progress thus allowing the program to return to the original schedule without overrun if serious technical problems can be avoided.

C. Work to be Performed in Next Report Period

Task I Update injector drawings to reflect improvement in manifolding design and incorporate modifications which would result in lower fabrication costs.

Task II Initiate fabrication of additional injector bodies.

Task III Complete preliminary design study of cooled chambers. Select two cooling concepts for final analysis and design.

III LOW PRESSURE TECHNOLOGY PROGRAM

A. Program Progress (Tasks XI through XX)

1. Task XI - Injector Analysis and Design

Design of the vane element cold flow test hardware was completed and submitted to the NASA/LeRC program manager for approval along with a cold flow test plan.

Stress and heat transfer analysis of the coaxial element injector have been completed. The results of this more detailed thermal analysis (shown in Figure III-1) indicate even lower temperatures than were predicted by the earlier parametric thermal study. The predicted thermal gradients were used as a basis for a thermal stress analysis of the face using various face materials. As a result of this effort, 0.25-in. OFHC copper has been selected for the injector face.

Design and analysis of the vaned element assembly has been initiated.

2. Task XII - Injector Fabrication

Fabrication of the coaxial element cold flow test hardware has been completed.

Preliminary fabrication steps have been initiated for the vane flow test hardware, film coolant injector, and components for the coaxial element assembly in anticipation of early approval for fabrication.

3. Task XIII - Thrust Chamber Design

Modification of the existing barrier temperature probe component designs to accommodate this chamber configuration have been completed. Thermal instrumentation has been identified and orders placed.

Task IV   Order materials to chamber fabrication

Task V   Task complete - No activity on igniter analysis and design.

Task VI   Continue igniter checkout tests with temperature conditioned propellants.

Task VII   Conduct valve actuation tests with temperature conditioned propellants.

Task VIII   Complete manifold cold flow tests for coaxial element design, install thermocouples on injector face and initiate hot checkout tests at nominal conditions.

Task IX   Continue with planning for J-4 altitude facility buildup.

Task X   Review flow measurement and response data from Task VIII for pulsing characteristics.

COAXIAL ELEMENT INJECTOR PREDICTED FACE TEMPERATURES

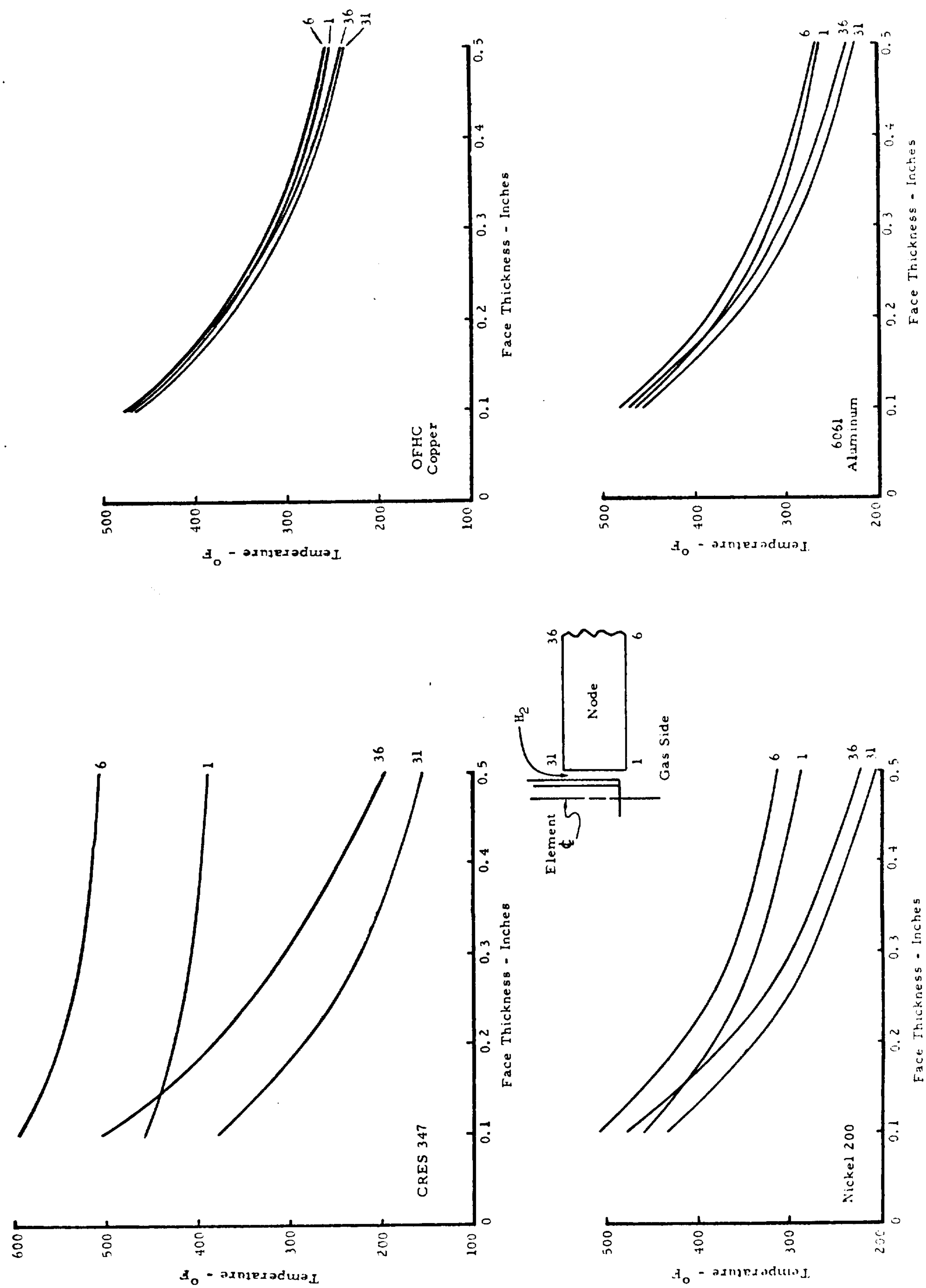


Figure III-1

4. Task XIV - Thrust Chamber Fabrication

Forgings and rolled and welded sections for the chamber and nozzle components have been ordered.

5. Task XV - Igniter Design and Analysis

The catalytic igniter design has been completed and submitted to the NASA project manager for review and approval. Design modifications to incorporate instrumentation have been initiated. Thermal instrumentation will measure the catalyst bed temperature at two axial stations as well as the oxygen sleeve temperature and the temperature of the fuel sleeve at two axial stations. Chamber pressure will be inferred from a secondary oxygen manifold pressure measurement.

Thermal analysis of the hydrogen-cooled igniter chamber indicated a modification to reduce the coolant passage gap (thereby increasing hydrogen coolant velocity) would reduce the gas-side wall temperature to less than $800^{\circ}F$. This modification has been incorporated. Predicted igniter chamber wall temperatures for O/F 50 combustion products are shown in Figure III-2.

A hydraulic analysis of the catalytic igniter was performed to size the secondary fuel coolant circuit, the secondary oxidizer circuit, and the hot gas core for design flow rates, pressures, and mixture ratios. In addition, a pressure drop analysis was conducted on the oxidizer and fuel feed circuits to the catalyst bed to determine if the design P_c and mixture ratio would be obtained in the core.

The design conditions were as follows: a P_c of 15 psia with a core mixture ratio of 1:1 prior to introduction of secondary oxidizer and 50:1 after mixing of the core and secondary oxidizer streams. The overall design mixture ratio including the fuel coolant was 4.9:1.

LOW PC CATALYTIC IGNITER
PREDICTED TORCH CHAMBER TEMPERATURE

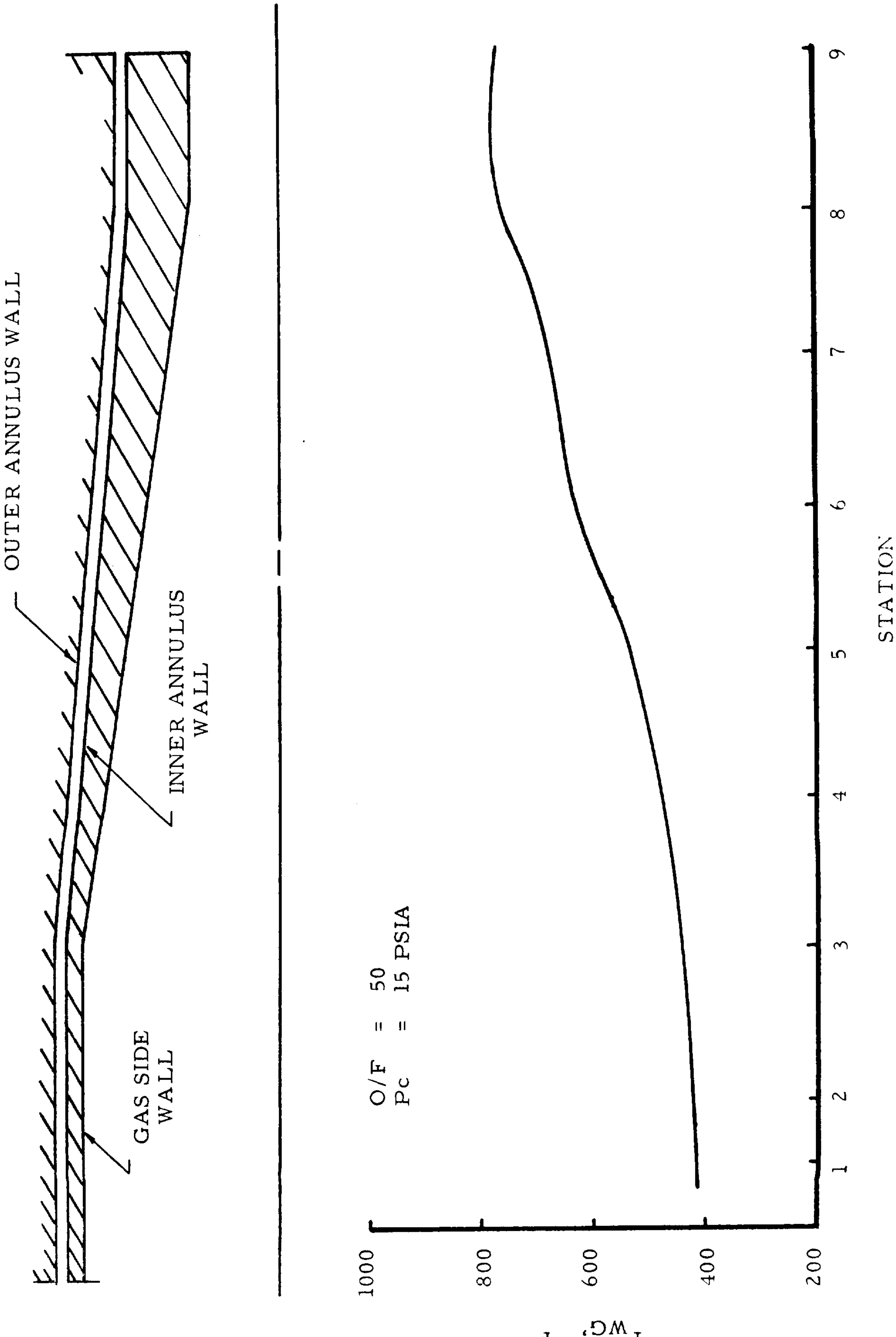


Figure III-2

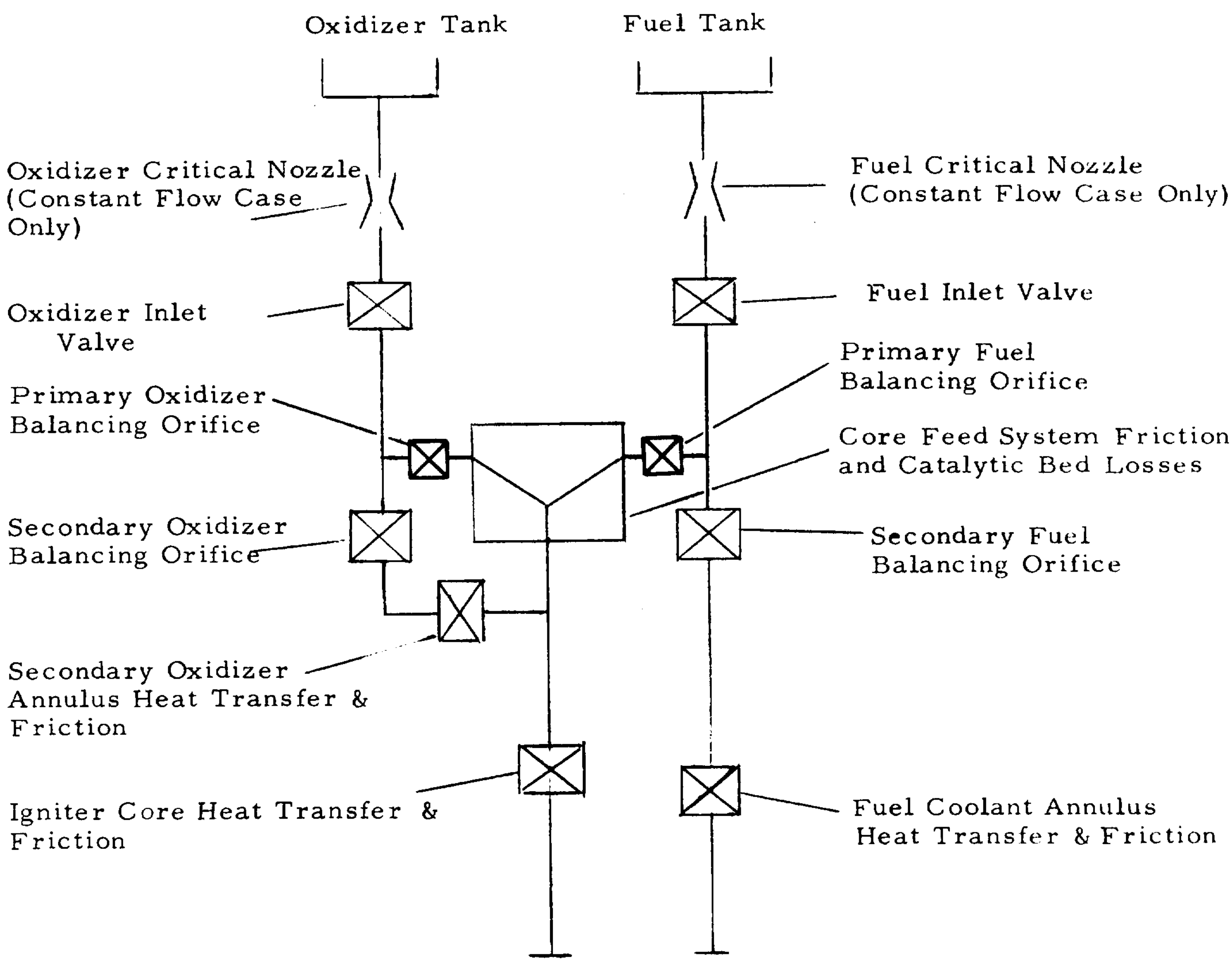
The analysis was done for two conditions corresponding to the existence or nonexistence of back pressure (back pressure is due to main chamber combustion). The back pressure range for the igniter was from 0 to 14.9 psia. The design technique was to size circuits for passage of design flow rates in the zero back pressure case (core and fuel coolant annulus throats choked), and then check the change in flow splits (mixture ratio shift) caused by finite back pressure (core and fuel coolant annulus throats unchoked).

The back pressure case analysis was conducted for two basically different system designs. Initially, a "soft" system was assumed, i.e., the oxidizer and fuel flow rates were reduced when the back pressure reached its steady-state value. The reductions were calculated and the core and overall mixture ratios examined for any variance from the design values. The second phase of the back pressure analysis considered a system with "critical" nozzles present upstream of the oxidizer and fuel inlet valves. The nozzles ensure constant fuel and oxidizer flow rates through the system with and without back pressure. This phase of the analysis determines if a core mixture ratio shift will occur for the constant flow rate system after establishment of steady-state back pressure.

A system schematic showing the basic interrelated hydraulic considerations for this analysis is shown in Figure III-3.

The results of the igniter hydraulic analysis along with values for the basic design parameters are listed in Table III-I. The terminology for the tabulated parameters are shown in Figure III-4. The secondary oxidizer and fuel annulus flow rates depend upon the temperature rise of the two streams. The cooling analysis predicts bulk temperature rises of 60°F for the secondary fuel and 50°F for the secondary oxidizer which were used in this analysis.

Back pressure case results for the variable flow "soft" system show the fuel coolant flow rate to reduce to approximately 68% of its design value while the core flow rate reduced to approximately 72% of



LOW PC CATALYTIC IGNITER HYDRAULIC ANALYSIS SCHEMATIC

Figure III-3

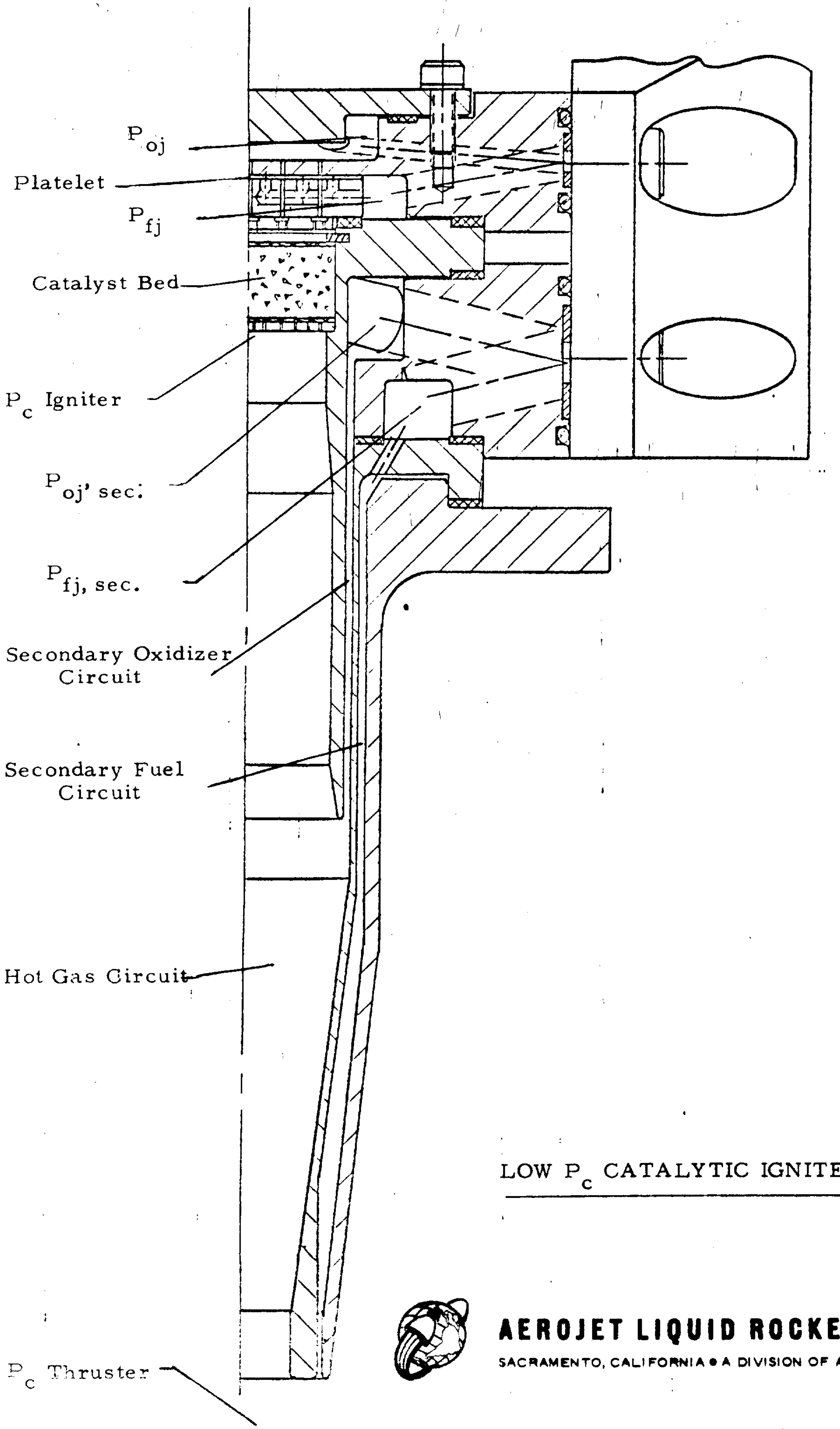
FLOW CHARACTERISTICS - LOW P_C CATALYTIC IGNITER

Pc Thruster (psia)	P_{oj} (psia)	P_{fj} (psia)	$P_{oj, sec}$ (psia)	$P_{fj, sec}$ (psia)	$\dot{W}_{o, core}$ (lbm/sec)	$\dot{W}_{f, core}$ (lbm/sec)	$\dot{W}_{o, sec.}$ (lbm/sec)	$\dot{W}_{f, sec}$ (lb/sec)	M. R. Core	MR Second.	MR Overall
0	20.0	20.0	18.5	17.90	.00125	.00125	.06125	.01145	1	50:1	4.92:1
Variable Flow											
14.90	20.0	20.0	19.22	19.03	.00090	.00090	.04416	.00776	1	50:1	5.20:1
Constant Flow											
14.90	23.0^{+}	22.0^{+}	23.0^{+}	23.0^{+}	.00125	.001479	.06125	.01122	.85	42:1	4.92:1

$^{+}P_{fj}$ & $P_{fj, sec}$ are actually a point upstream of the fuel balancing orifice

P_{oj} & $P_{oj, sec}$ are a point upstream of the oxidizer balancing orifice

Table III-I



LOW P_c CATALYTIC IGNITER TERMINOLOGY

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Figure III-4

its design value. This finding would indicate a slight lowering of the catalytic bed mixture ratio for a constant flow rate system as back pressure is increased.

This finding was confirmed in the second phase of the back pressure analysis, i.e., the constant flow rate system showed an increase of throat inlet stagnation pressure as back pressure developed. The magnitude of the fuel catalytic bed overflow was calculated to be approximately 2% of the design fuel coolant flow rate which would lower the bed mixture ratio to a value of approximately 0.8. Satisfactory operation of this igniter is anticipated with any of the four combinations possible due to back pressure variation or propellant feed system configuration.

6. Task XVI - Igniter Fabrication and Checkout

Estimates and planning for the fabrication of the catalytic igniter have been completed. Fabrication will be initiated after design approval is received.

7. Task XVII - Bipropellant Valves Preparation

Modification of valve components, fabrication of new components, and procurement of standard items has been initiated. Cleaning and assembly of the thrust chamber valves is nearing completion prior to leak and proof testing in the next report period. Procured and manufactured components are scheduled for delivery early in the next report period.

Structural analysis of the valve components has been completed. This analysis was based on a 20-millisec valve travel time, a nearly constant velocity profile after initial actuator acceleration to 9 ft/sec, and 2000 psi actuation pressure.

The results indicate a cycle life of at least 3000 cycles for the Belleville spring snubbers and 10,000 cycles for other structural components. The butterfly shaft to actuation level arm wedge pin incurrs somewhat high contact stresses and an exact analysis of cycle life is not withinthe scope of this activity. A plan will be initiated for routine inspection to determine if brinelling and loosening of the pin has occurred.

8. Task XVIII - Injector Testing

Cold flow tests of the coaxial element have been completed. Data reduction is in process to be followed by data evaluation and the selection and recommendation of an element configuration for hot fire testing.

Twenty-six configurations were tested to determine mixture ratio distribution and seventeen configurations were selected for the mass distribution tests. Numerous test data points were measured for each configuration to determine element symmetry and to evaluate the mixing characteristics at various distances from the element end. The tests are summarized in Table III-II.

Parameters investigated in these series were: oxygen element inlet configuration (three swirlers, one pressure drop and distribution cap design and a thorough flow baseline design), fuel injection velocity differences and element end sacrf angle.

9. Tasks XIX and XX

No Activity

B. Current Problems

No significant technical problems have been encountered. Some minor schedule slippages have been encountered and are indicated on the Contract Program Schedule.

LOW PC APS

COAXIAL ELEMENT COLD FLOW TEST PROGRAM

SUMMARY

Test Series	Test Points	MR	Axial Loc.	Rotation	Recess	Element
Temperature						
T-1	1-73	2-4	0-3	0-270	0	Normal Coax
T-2	74-107	2-4	0-3	0-270	.5	Normal Coax
T-3	108-139	2-4	0-3	0-270	1.0	Normal Coax
T-4	140-143	2-5	0-3	0	0	1 Hole ΔP Ox Cap
T-5	144-175	2-4	0-3	0-270	0	6 Hole ΔP Ox Cap
T-6	176-207	2-4	0-3	0-270	0	2 Hole Ox. Swirler
T-7	208-239	2-4	0-3	0-270	0	4 Hole Ox. Swirler
T-8	240-271	2-4	0-3	0-270	0	Inline Swirler
T-9	272-294	2-4	0-3	0-270	.5	6 Hole ΔP Cap
T-10	295-317	2-4	0-3	0-270	.5	2 Hole ox. Swirler
T-11	318-340	2-4	0-3	0-270	.5	4 Hole Ox. Swirler
T-12	341-363	2-4	0-3	0-270	.5	Inline Swirler
T-13	364-386	2-4	0-3	0-270	.5	Inline Swirler
T-14	387-396	2-5	0-3	45-315	0	45 Deg. Scarf W/Flush Fuel Face and 6 Hole Cap
T-15	397	2-5	.5	45	0	45 Deg. Scarf W/Flush Fuel Face and 6 Hole Cap
T-16	398-429	2-4	0-3	0-270	.5	6 Hole ΔP Cap W/High Velocity Fuel ANN
T-17	430-456	2-4	0-3	0-270	.5	2 Hole Swirler W/High Velocity Fuel ANN
T-18	457-461	2-5	0-3	0	.5	4 Hole Swirler W/High Velocity Fuel ANN
T-19	462-471	2-5	0-3	0-270	0	45 Deg. Scarf W/6 Hole Cap
T-20	472-481	2-5	0-3	0-270	0	45 Deg. Scarf W/Inline Swirler
T-21	482-491	2-5	0-3	0-270	.5	45 Deg. Scarf W/6Hole Cap
T-22	492-501	2-5	0.3	0-270	.5	45 Deg. Scarf W/Inline Swirler
T-23	502-512	2-5	0-3	0-270	0	22.5 Deg. Scarf W/6 Hole ΔP Cap

Table III-IIa

Test Series	Test Points	MR	Axial Loc.	Rota-tion	Recess	Element
Temperature (cont.)						
T-24	513-522	2-5	0-3	0-270	0	22.5 Deg. Scarf W/Inline Swirler
T-25	523-532	2-5	0-3	0-270	.5	22.5 Deg. Scarf W/6 Hole ΔP Cap
T-26	533-542	2-5	0-3	0-270	.5	22.5 Deg. Scarf W/6 Hole ΔP Cap
Pressure						
P-1	1-57	2-4	0-3	0-90	0-1.0	Normal Coaxial
P-2	58-77	2-4	0-3	0-90	0	6 Hole Ox ΔP Cap
P-3	78-97	2-4	0-3	0-90	0	2 Hole Swirler
P-4	98-117	2-4	0-3	0-90	0	4 Hole Swirler
P-5	118-137	2-4	0-3	0-90	0	Inline Swirler
P-6	138-153	2-4	0-3	0	.5	Inline Swirler
P-7	154-169	2-4	0-3	0	.5	2 Hole Swirler
P-8	170-185	2-4	0-3	0	.5	4 Hole Swirler
P-9	186-201	2-4	0-3	0	.5	6 Hole ΔP Cap
P-10	202-218	2-4	0-3	0	.5	6 Hole ΔP Cap W/High Fuel Velocity ANN
P-11	219-234	2-4	0-3	0	.5	2 Hole Swirler W/High Fuel Velocity ANN
P-12	235-238	2-5	0-3	0	.5	4 Hole Swirler W/High Fuel Velocity ANN
P-13	239-258	2-5	0-3	0-270	0-.5	45 Deg. Scarf W/6 Hole ΔP Cap
P-14	259-278	2-5	0-3	0-270	0-.5	45 Deg. Scarf W/Inline Swirler
P-15	279-298	2-5	0-3	0-270	0-.5	22.5 Deg. Scarf W/6 Hole Cap
P-16	299-318	2-5	0-3	0-270	0-.5	22.5 Deg. Scarf W/Inline Swirler
P-17	319-342	2-4	ΔP Survey Various Oxidizer Elements			

Table III-IIb

C. Work to be Performed in the Next Report Period

Task XI

Complete coaxial element assembly design incorporating cold flow test results.

Complete vaned element assembly analysis and design.

Task XII

Fabricate vaned element cold flow hardware

Complete fabrication of coaxial element injector assembly

Complete fabrication of film coolant ring

Initiate fabrication of vaned element assembly components

Task XIII

Initiate cooled chamber design effort

Task XIV

Initiate instrumentation of heat sink chamber

Task XV

Prepare catalytic igniter test plan

Task XVI

Obtain approval for and initiate fabrication on catalytic igniter

Task XVII

Complete fabrication, assembly and functional checkout of valves. Initiate bench testing.

Monthly Report No. 3

Task XVIII

Conduct vaned element cold flow tests

Task XIX and XX

No Activity Planned

FORECAST AND CONSUMPTION OF GOVERNMENT-FURNISHED PROPELLANT - NAS 3-14354

	LO_2 (tons)		LH_2 (lb)		LN_2 (tons)		GHe (SCF)	
	Forecast	Actual	Forecast	Actual	Forecast	Actual	Forecast	Actual
Aug 1970					5	0	12,000	3,000
Sep 1970	2	0	3,000	0	15	0	27,500	16,000
Oct 1970	7	0	4,750	0	15	0	33,500	12, 300
Nov 1970	7		4,000		15		1,000	
Dec 1970	8		5,000		25		1,500	
Jan 1971	6				15		1,000	
Feb 1971	7				15		1,000	
Mar 1971	1.5				10			
Apr 1971	1.5				25		4,500	
May 1971	5				35		6,000	
Jun 1971	3				25		4,500	
Jul 1971					10		2,500	
Expected Total	48		16,750		210		95,000	

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Lewis Research Center

CONTRACT PROGRESS SCHEDULE

REPORT FOR MONTH ENDING: 25 October 1970

FORM APPROVED BUDGET BUREAU NO 104-R0007

9. NASA Use Only — a. NASA CODE — b. PROJECT MGR — c. EVALUATION DATE — d. EXCEPTION CATEGORY — e. — f. — g.

1. CONTRACT TITLE: Hydrogen-Oxygen APS Engines (HiP$_c$)

2. CONTRACTOR (Name and address): Aerojet Liquid Rocket Co., P.O. Box 12333, Sacramento, California 95813

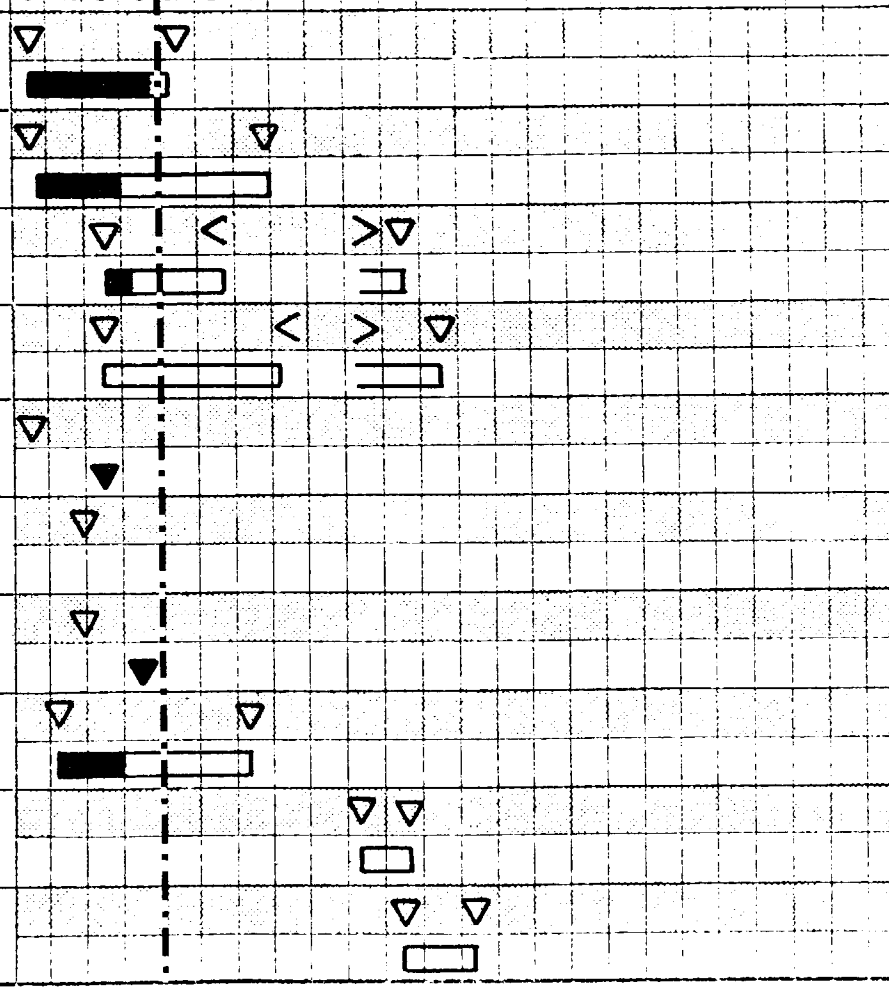
3. CONTRACT NO.: NAS 3-14354

4. APPROVED (Contractor's Project Manager): L. Schoenman

PREPARATION DATE: 11-5-70

5. NASA APPROVED SCHEDULE DATE: 8-31-70

7. 1970 / 1971 — J A S O N D J F M A M J J



Task	6. Reporting Category	8. Tech Objective % Comp.
I	Injector Analysis and Design	95
II	Injector Fabrication	24
III	Thrust Chamber Analysis and Design	18
IV	Thrust Chamber Fabrication	0
V	Ignition System Analysis and Design	100
VI	Ignition System Fabrication and Checkout	85
VII	Bipropellant Valve Preparation	100
VIII	Injector Tests	6
IX	Thrust Chamber Cooling Tests	0
X	Pulsing Tests	0

NASA-C (Rev 1-65)

NASA APPROVED SCHEDULE

CONTRACTOR'S WORKING SCHEDULE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Lewis Research Center

CONTRACT PROGRESS SCHEDULE

REPORT FOR MONTH ENDING: 25 October 1970

FORM APPROVED BUDGET BUREAU NO 104-R0007

1. CONTRACT TITLE: Hydrogen-Oxygen APS Engines

2. CONTRACTOR (Name and address): Aerojet Liquid Rocket Co., P.O. Box 13222 Sacramento, California 95813

3. CONTRACT NO.: NAS 3-14354

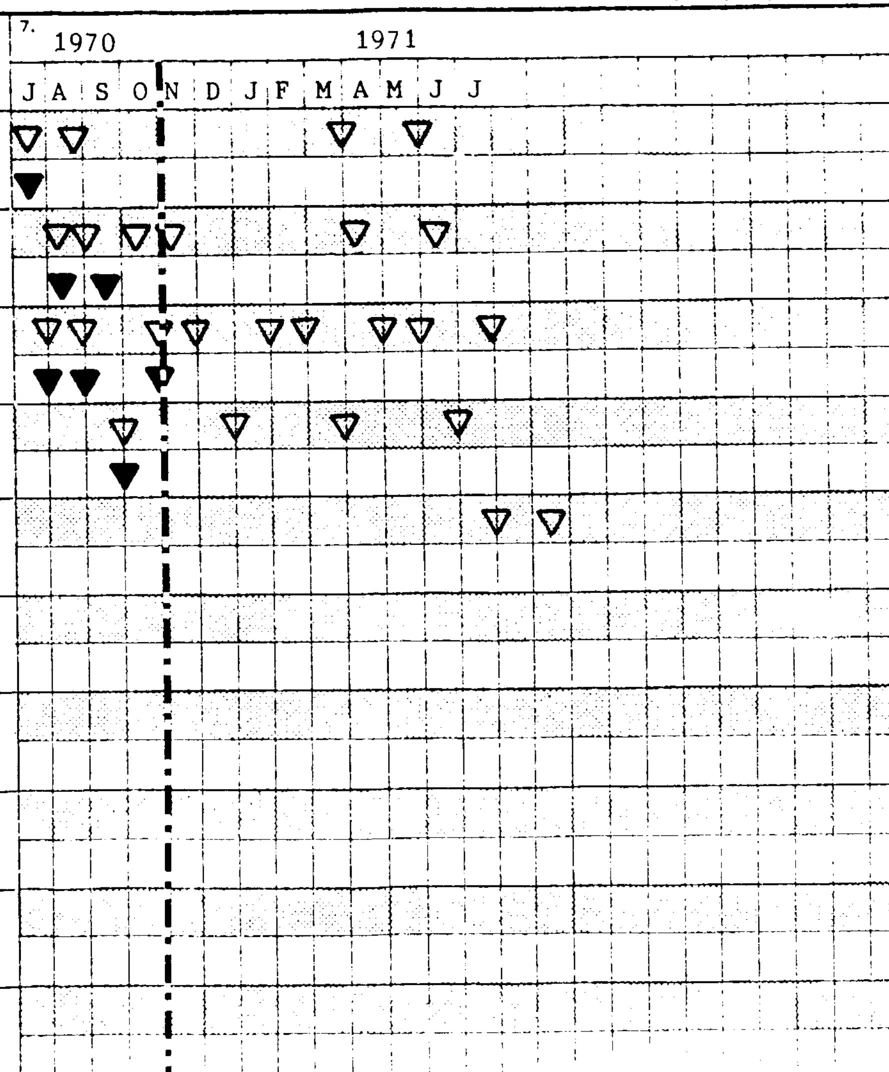
4. APPROVED (Contractor's Project Manager): l. a. Oare

PREPARATION DATE: 11-2-70

5. NASA APPROVED SCHEDULE DATE: 8-31-70

9. NASA Use Only: a. NASA CODE; b. PROJECT MGR.; c. EVALUATION DATE; d. EXCEPTION CATEGORY; e.; f.; g.

Task	6. REPORTING CATEGORY	8. TECH OBJECTIVE % COMP.
XXI	Program Plan and Test Plans High P_c	25
	Low P_c	33
	Monthly Reports	33
	Quarterly Reports	25
	Final Report Draft	0



NASA-C-62 (Rev. 7-65)

NASA APPROVED SCHEDULE
CONTRACTOR'S WORKING SCHEDULE